

The Magnitude and Frequency of Floods in the Niger Delta Basin of Nigeria

Dr. Agusomu, Tano Dumoyei & Dr. Eli, Horsfall Digieneni

*Department of Geography and Environmental Management,
Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.*

Email: dumoyei@yahoo.com

ABSTRACT: *The Niger Delta Basin is well known for its annual and sporadic floods. The aim and objectives of this study, therefore, are focused on determining the magnitude and frequency of the observed floods, the rainfall characteristics that influences the occurrence of the observed flood magnitudes, the maximum volume of flood events expected to be equaled or exceeded in any given number of years in the basin; the conditions associated with human activities that constitute the risk of flooding; and the resource users' perception of flooding in the basin. In order to achieve these objectives, data acquisition was accomplished by the collection of historical records of rainfall events, field observations and interviews with six hundred householders drawn from riverine communities critically prone to flooding in the region. The analysis of rainfall events indicated a general trend of increasing rainfall events in the region in recent times with a marked temporal and spatial variability. The expectable annual minimum and maximum flood magnitudes for selected communities were determined. On the perception of flooding, the respondents, in the absence of relevant technologies, made crude estimates of the magnitudes and areal extents of flooding in the region but lacked any perception of the frequency of severe floods in the region.*

INTRODUCTION

Though it is easy to define the term flood, perhaps it is enough to say that a condition of flood exists when the discharge of a river cannot be accommodated within the margins of its normal channel, so that water spreads over adjoining grounds on which crops or forest are able to flourish (Strahler and Strahler, 2004).

Generally, floods are extreme hydrometeorological events resulting in the inundation of usually dry places by a great quantity of water. Because there are differences in flood potentials that exist among lithologic and topographic types; it is necessary to generalize flood experience over geographic areas. Flood events are common occurrences in the floodplains of rivers, and in recent times, in many urban centres (Gregory, 1973).

Devastating floods have occurred in Nigeria, and these may be conceived as usually resulting from intense rainfalls which can be very destructive to life and property. The largest area in the country subject to annual flooding is the Niger Delta Basin (NDRMP 2007). Other parts of the country which experience periodic floods include Ibadan (1980), Benin (1978), Kano (1988), Jos (1995), Rigasu and Kabala, West of Kaduna State. Ibadan is noted for its long history of floods. Before 1946, floods were relatively rare in the city, since that year, Ibadan has witnessed at least five major floods. In all these, the flood of 1980 was the worst. About 200 people died and more than 50,000 residents along the floodplains of Ogunpa and Kudeti Rivers which drain the city were rendered homeless and while property and merchandise worth millions of naira was washed away or irretrievably damaged by the flood (NDRMP 2007). Indeed, many areas in southern Nigeria are flood prone. In fact, the entire freshwater swamp zone of the Niger Delta Basin was completely submerged in the 2012 floods.

Floods are not limited to the southern part of the country. The situation has been the same in the northern part. In Kano State, for example, the flood of August 1988 killed 33 persons, rendered 200,000 homeless and damaged property worth over 3 million naira. The floods which lasted for three days (13-15 August) affected 14 of the then 20 local government areas of the state (African Concord, 5th September, 1988). In 1995, floods also affected Jos. Areas most affected were Angwan Rukuba, Angwan Rogo and parts of Bukuru, where many lives were lost and much property destroyed (Agusomu, 1999).

The foregoing represents what may be a representative sample of floods and their effects on people and the environment in Nigeria. No doubt, considerable attention has been devoted to flood problems in Nigeria which is concentrated more in urban areas. Moreso, the reports and publications that have been compiled have been largely concerned with the causes and extent of floods and flood damage (Marshall, 2008; Leigh and Low, 1983; Abbott, 2004); or have examined possible strategies for alleviating flooding including localized protection schemes; more adequate land use planning and integrated catchment development (Colman, 2002; Criss and Shock, 2001; and Eli, 2012). Despite their potential value for development planning purposes, very little information is available on the magnitude and frequency of floods on a regional basis. It is thus obvious that a study on, and a foreknowledge of the magnitude and frequency of occurrence of floods in the Niger Delta Basin of Nigeria would minimize the perennial risk encountered in floodplain development in the basin.

In the Niger Delta Basin, natural gas flaring has contributed substantially to the emission of greenhouse gasses which in turn influences increases in temperature and abnormal annual variations in rainfall patterns; combined with global warming and its possible impact has led to a sea-level rise in the Gulf of Guinea. Communities in the coastal areas of the region may suffer more severe problems from the eventual increase in the sea level and hydrometeorological events. Projected sea level rise alone is expected to cause increased coastal erosion, loss of land and property, and a dislocation of people. Other adverse impacts are noticed in the areas of limited arable land and soil salinization which makes agriculture in the coastal areas more vulnerable and risky (Roderick, 2004).

The analysis of floods on magnitude-frequency basis in the region therefore seeks to predict the maximum volume of flood expected to be equaled or exceeded in a given number of years. The practical significance of the study derives from the application of flood forecasting for abatement and control, and for the design of various hydraulic and water resources structures. In order to control floods properly and to design and locate dams, bridges, culverts, highways, railroads, residential and industrial buildings, water supply and sewage works, and other facilities, it has become necessary to evaluate the magnitude and probable frequency of flood events in the Niger Delta Basin of Nigeria.

THE RESEARCH PROBLEM

In the last forty years, the Niger Delta Basin has witnessed a tremendous growth in population and expansion of urban structures. Communities in the coastal areas suffer immensely from downstream floods attributable in part to intense rainfall, misuse of river channels, and the negative impacts of oil mineral exploration and exploitation activities in the region. Natural gas flaring and global warming has contributed substantially to the emission of greenhouse gases which in turn have triggered off high temperatures, rainfall and a sea level rise, as well as flooding in the region, adversely affecting agriculture, subsistence and population distribution (Roderick, 2004). This study therefore seeks to answer the following research questions:

1. What is the magnitude of floods in the Niger Delta Basin of Nigeria?
2. What is the maximum volume of flood events expected to be equaled or exceeded in a given number of years in the basin?
3. What rainfall characteristics influence the occurrence of the observed flood magnitudes in the basin?
4. What conditions associated with human activities constitute the risk of flooding vis-à-vis the observed rainfall characteristics in the basin?
5. How do resource users perceive floods and flood hazards in the Niger Delta Basin of Nigeria?

AIM AND OBJECTIVES

Floodplain occupancy seems to be growing at a more rapid rate than the overall population growth rate of Nigeria. Flood losses therefore seem destined to continue to mount. Studies of floods are therefore aimed at providing information necessary for understanding the possible courses of action that can be taken to reduce the impending toll of flood losses (Agusomu, 1999). The aim of this study therefore is focused on determining the magnitude and frequency of the recurring flood events in the Niger Delta Basin of Nigeria, using the regional flood magnitude-frequency approach, as well as understanding how floodplain dwellers (resource-users) respond to flood hazards and the resultant environmental stress experienced. To achieve this aim, the following objectives were considered, viz:

- a. To determine the magnitude of floods in the Niger Delta Basin.
- b. To determine the rainfall characteristics that influences the occurrence of the observed flood magnitudes in the Niger Delta Basin of Nigeria.
- c. To determine the human activities that constitutes the risk of flooding vis-à-vis the observed rainfall characteristics in the basin.

- d. To determine the extent to which variations in perception of floods and flood hazards is associated with resource use and development in the basin.

THE STUDY AREA

The Niger Delta Basin is located between latitudes $4^{\circ} 00'$ and $15^{\circ} 30'$ north of the Equator, and longitudes $5^{\circ} 30'$ and $7^{\circ} 37'$ east of the Prime Meridian. The Niger Delta Basin, situated in the southern part of Nigeria and bordered to the south by the Atlantic Ocean along the coast of West Africa, extends in a curved shore of about 480 kilometres from the Benin River in the west to the Bonny River in the east. Inland, it begins below the village of Aboh where the Niger River forks into the Nun and the Forcados Rivers. The basin is a low-lying region that is riddled with an intricate system of natural channels through which the river finds its way into the sea (Fig.1).

The region covers approximately 80,100 square kilometres of Nigeria's total land area within the Equatorial Climatic zone. Its greatest distance from east to west is approximately 264 kilometres, and from north to south is about 157 kilometres. The average population density here was computed at 137 persons per square kilometres (NDRDM, 2007).

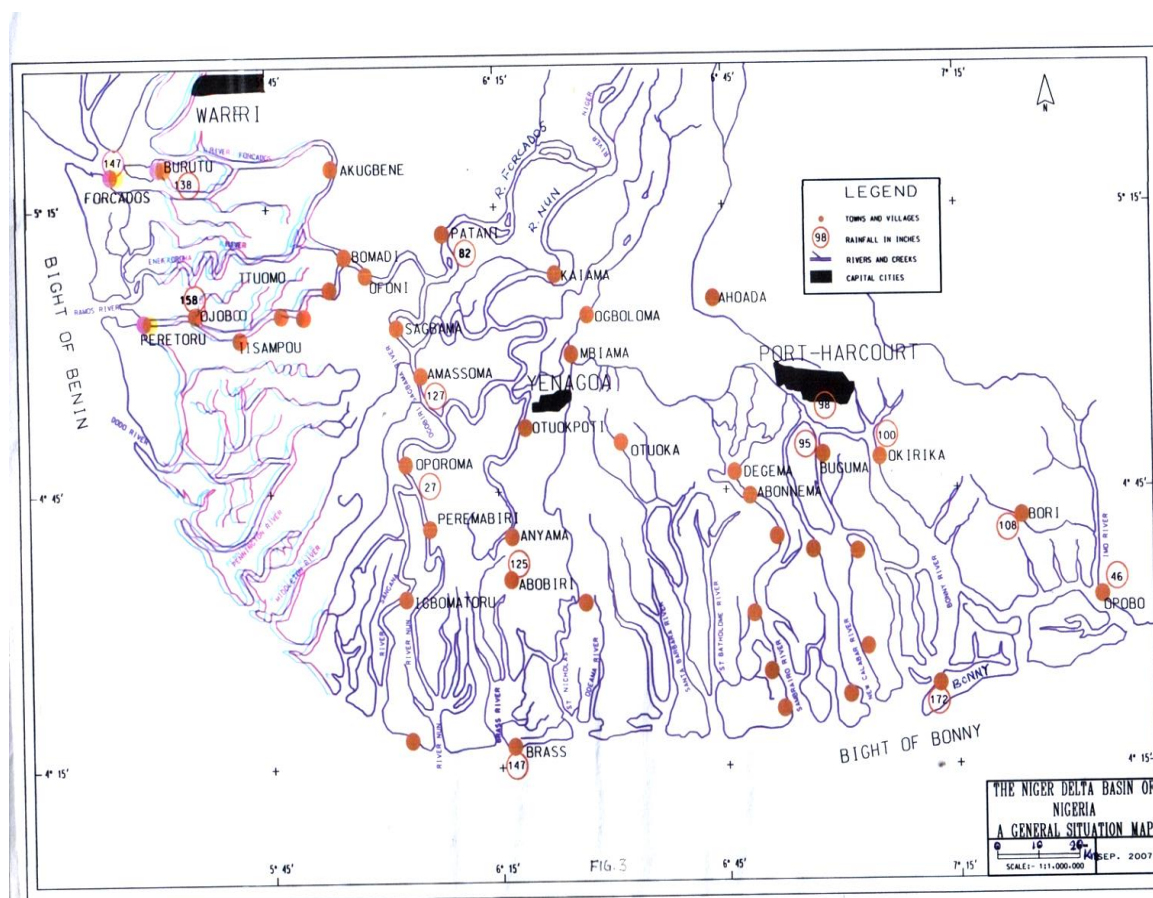


Fig.1. The Niger Delta Basin of Nigeria: A General Situation Map (NDRDMP, 2007)

MATERIALS AND METHODS

In order to achieve the aim and objectives of the study, a range of data were collected and these included the following data sets:

- a. Data on the magnitude of recurrence flood events in the Niger Delta Basin. These are data required in terms of determining the inundation height in metres, duration, areal extent and the speed of flood onset at selected stations.
- b. Data on the physical and climatic characteristics of the basin such as the drainage area, basin slope and rainfall data - the rainfall intensity, duration and the amount of storm – rainfall at selected at selected stations, and;
- c. Data on the perceived causes of flooding and the adjustments made in the region.

These data sets were collected from primary and secondary sources for the study. The primary data sets were sourced by direct field methods of observations, measurements and interviews. Secondary data acquisition, on the other hand, was achieved by obtaining 31 years (1976-2006) records of daily and annual rainfall magnitudes from the Nigeria meteorological services and the Niger Delta University station.

For flood magnitude and frequency analysis, estimates required for various engineering designs (for example, bridges, culverts, dams and other hydraulic structures), the statistical and physical approaches were employed. The statistical approach is based on the probability theory and the two distributions most often used here are; (i) the normal distribution function and (ii) the extreme-value distribution function developed by Gumbel (1941). The requirements of the Gumbel's Extreme-Value Theory is to define for each recorded flood the recurrence-interval, that is, the average span of time between two successive floods of that particular magnitude. The recurrence-interval (r.i) is calculated by means of the simple equation:

$$r.i = \frac{n + 1}{r}$$

Where:

- r.i = The recurrence-interval in years
 n = The total number of items in the series
 r = The ranking order of a particular flood or observations

In this study, the analysis of rainfall data was based on the maximum daily September rainfall occurring in each year from 1976 to 2006 from selected stations in the Niger Delta Basin. The maximum daily September rainfall in the point stations of Yenagoa, Warri, Port Harcourt and the outlier station of Owerri were analyzed to define for each station the recorded flood recurrence-interval or return period that is likely to be equaled or exceeded. The other analytical techniques employed in the study for flood producing rainfall events include the 3-year moving mean curve, the coefficient of variation index, the standardized rainfall anomaly index, the areal depth of rainfall and the simple regression analysis for determining rainfall fluctuations in the Niger Delta Basin.

FORMULAE:

i. The 3-year moving mean index:

For a three year moving mean, the various values of rainfall plotted against time (mean of 3 years) were calculated as:

$$P_1^1 = \frac{P_1 + P_2 + P_3}{3} ; P_2^1 = \frac{P_2 + P_3 + P_4}{3} ; P_3^1 = \frac{P_3 + P_4 + P_5}{3}$$

$$\therefore P_2^1 = \frac{P_{n-2} + P_{n-1} + P_n}{3} \text{ ----- (2)}$$

The values of $P_1, P_2, P_3 \text{ ----- } P_n$ were then plotted against the corresponding time. The plot so obtained is known as the 3-year moving mean curve of annual rainfall. 1

ii. The Coefficient of Variation Index

The annual rainfall variability in the Niger Delta Basin was analyzed using the Coefficient of Variation Index. This index was described by Barry (1969) as an efficient and preferred measure used to compare the deviations for places with average rainfall values, and is expressed in percentage of the calculated mean, viz:

$$C.V (\%) = \frac{SD}{\bar{P}} \times 100 \text{ ----- (3)}$$

Where:

- C.V. (%) = Coefficient of Variation

S.D	=	Standard Deviation of Observations
P	=	Mean of Observations

iii. The Standardized Rainfall Anomaly Index

The value for the year is expressed by:

$$I.A.V. = \frac{(P_t - \overline{P_t})}{SD} \quad (4)$$

Where:

$\overline{P_t}$	=	Absolute value of precipitation
$\overline{P_t}$	=	Mean of the series
SD	=	Standard Deviation
I.A.V	=	Normalized inter-annual variation

iv. Average Depth of Precipitation

The average depth of precipitation, also termed the equivalent uniform depth of rainfall of the study area was determined using the arithmetic mean method (also known as the unweighted mean method). This is the mean of the precipitation gauges located within the basin or catchment. Thus,

$$P_t = P_1 + P_2 + \dots + P_n = \frac{\sum P_1}{n} \quad (5)$$

Where:

P_t	=	Areal Precipitation
P_1	=	Precipitation at gauge 1
n	=	Total number of gauge stations

This method, though the simplest, was adopted because:

- The topography of the region is relatively flat
- The gauge stations used are to a large extent, evenly distributed.
- The spatial variation of precipitation in the region is small.

v. Simple Linear Regression Analysis

The formula for Simple Linear Regression Analysis is:

$$Y = a + bx \quad (6)$$

$$\text{Where } b = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})^2}$$

$$a = \bar{y} - b \bar{x}$$

Where:

a = the base intercept

b = the regression coefficient or slope,

$\bar{x}$ = rainfall values

$\bar{y}$ = years.

Although there are several methods for finding the equation of the regression line stated above, the purpose of the regression line is to enable the researcher see the trend and make predictions on the basis of the data collected.

On the response to flooding, six hundred householders were interviewed and their responses regarding to their perception and adjustments to floods are analyzed and reported herein.

RESULTS AND DISCUSSION

Rainstorm Characteristics of the Niger Delta Basin

Rainfall data obtained from the Nigerian meteorological Services, Oshodi-Lagos and the Niger Delta University Stations were analyzed and the magnitudes obtained were used to make reasonable probabilistic estimates of rainfall for design purposes. The rainfall data of seven stations (that is, Ahoada, Bomadi, Degema, Owerri, Port Harcourt, Warri and Yenagoa) were totaled to yield monthly, seasonal and annual rainfalls, covering a period of 31 years. The annual rainfall data of these stations are presented graphically in Figure 2(a-g).

The graphical representations, however, showed no persistent regular cycles or trends in the rainfall pattern due to the wide variations in the consecutive years of precipitation. In order to smoothen out the observed variations, and to indicate trends or cyclic patterns, 3-year moving average curves were constructed and superimposed over the original sequence of the Owerri, Port Harcourt, Warri and Yenagoa stations' bar graphs, and these are shown in Figures 3(a-d) respectively.

The curves of the 3 year moving mean (Figure 3) indicate a general trend of increasing rainfall events in the basin except for the periods between 1986-1989 and 1995-2001 which indicated decreased annual precipitation in the region. Owerri, an outlier station of the Niger Delta Basin, with a lower incidence of rainfall also indicated increasing trends except for the periods between 1980-1983 and 1995-2001. Apparently, there is a cyclical pattern of rainfall events in the Niger Delta Basin.

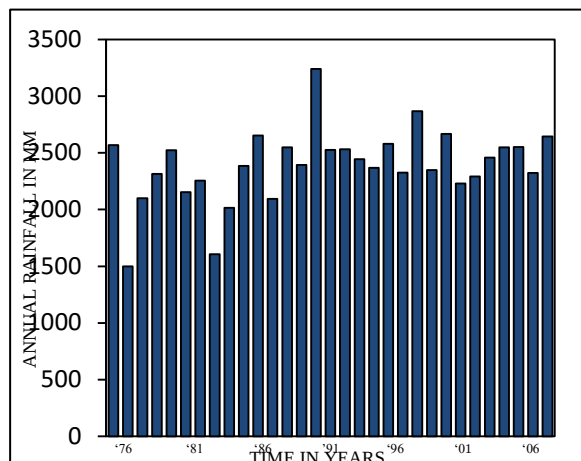


Fig. 2(a): Annual Rainfall in Ahoada (1976-2006)

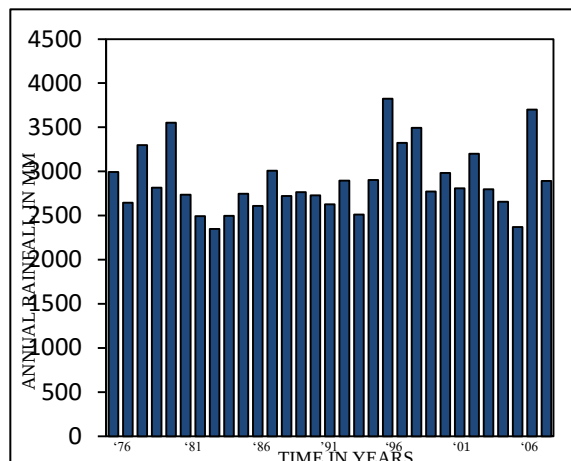


Fig. 2(b): Annual Rainfall in Bomadi (1976-2006)

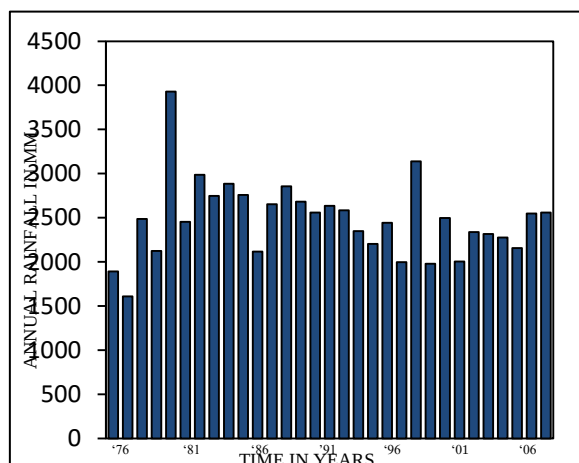


Fig. 2(c): Annual Rainfall in Degema (1976-2006)

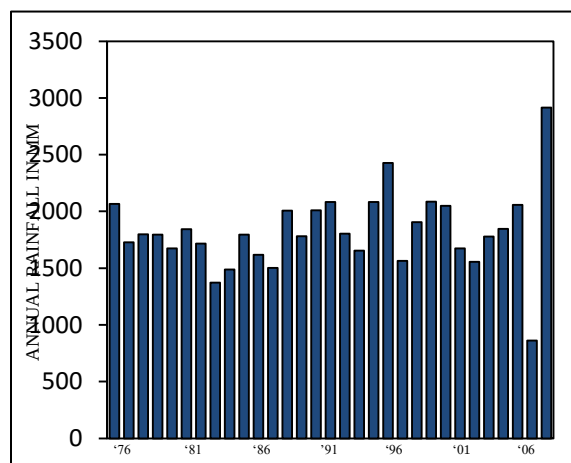


Fig. 2(d): Annual Rainfall in Owerri (1976-2006)

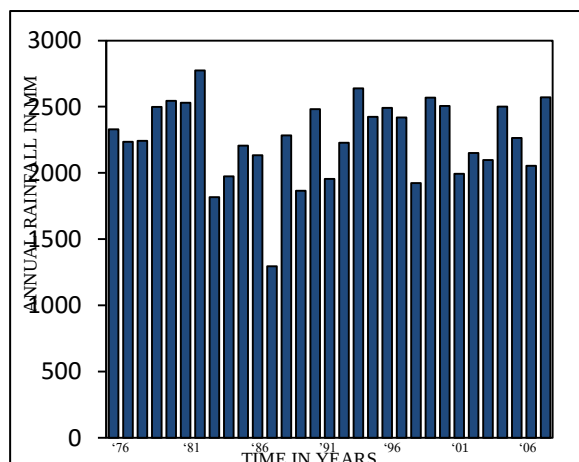


Fig. 2(e): Annual Rainfall in Port-Harcourt (1976-2006)

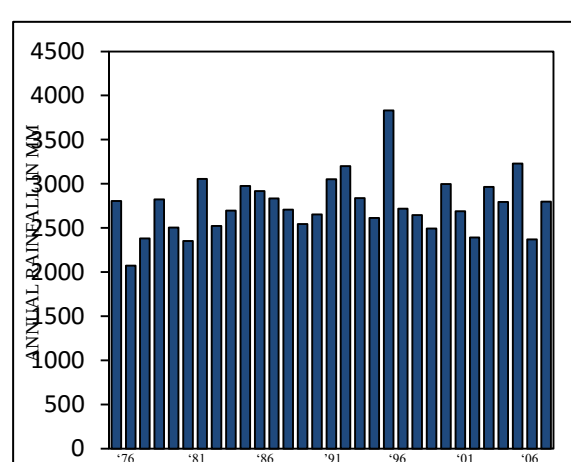


Fig. 2(f): Annual Rainfall in Warri (1976-2006)

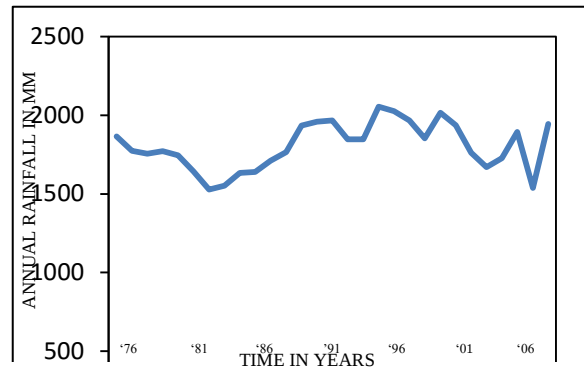
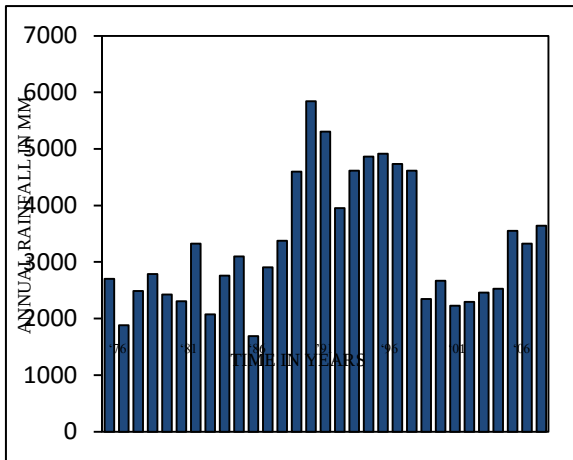


Fig. 3(a): 3 - Year Moving Average Rainfall Curve for Owerri (1976-2006)

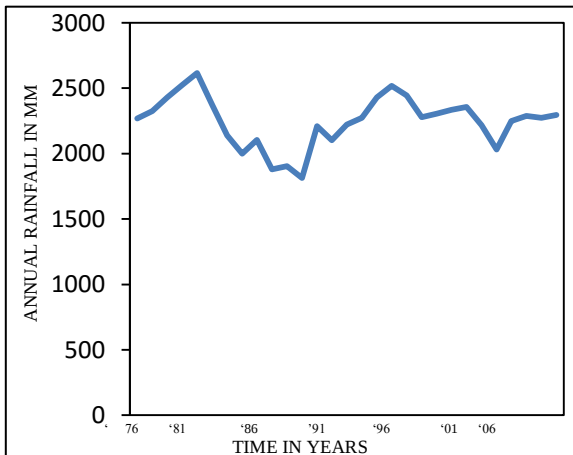


Fig 3(b): 3 - Year Moving Average Rainfall Curve for Port-Harcourt (1976-2006)

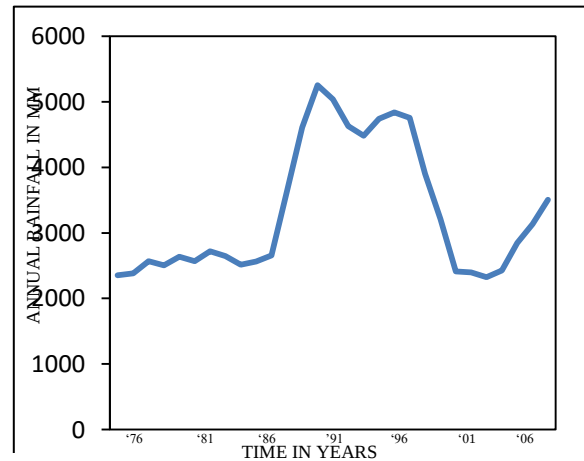


Fig. 3(c): 3 - Year Moving Average Rainfall Curve for Yenagoa (1976-2006)

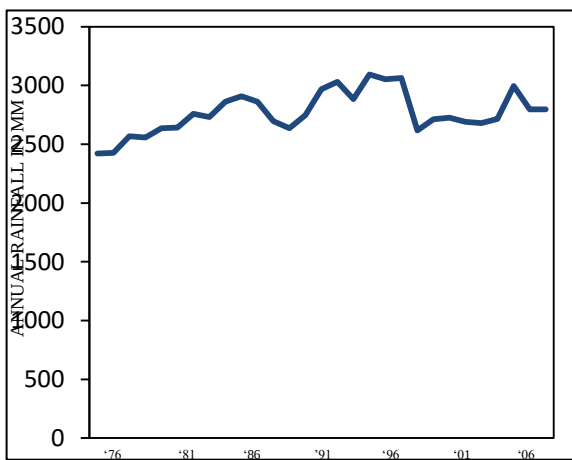


Fig 4(d): 3 - Year Moving Average Rainfall Curve for Warri (1976-2006)

KEY

'76	-	1976
'81	-	1981
'86	-	1986
'91	-	1991
'96	-	1996
'01	-	2001
'06	-	2006
SAI	-	Standardized Anomaly Index

ANNUAL RAINFALL VARIABILITY

In the Niger Delta Basin, the coefficient of variation for annual rainfall ranges from about 10% in the south to 13% in the north. Figure 4 shows the variability of annual precipitation in the region. However, the coefficient of variation takes no account of the sequence of the observed data (Barry, 1969). Therefore the inter-annual rainfall variations of selected stations were computed and these are shown in Figure 5.

The standardized rainfall anomaly index was used for the computation of the inter-annual rainfall variations. The analysis of the inter-annual rainfall variability, using the standardized rainfall anomaly index (Fig. 5a-e), showed that rainfall varies from year to year in each of the stations, and also from location to location in the Niger Delta Basin. At Degema station, wet and dry years alternated between 1976 and 1979. The station was generally wet in the 1980s. While rainfall was quite variable in the 1990s, an increase in rainfall events is noticeable till date. The Port Harcourt station showed a high variability of rainfall events. About 15 years of the period under consideration were evidently below the normalized mean of the station and were therefore considered to be dry. From 1998 to date rainfall is however on the increase in the station, leading to severe flooding in the region.

The Warri station was observed to have had more of below mean rainfall events as above. Sixteen years of the 31 year period under study were dry. Nevertheless, the late 1990s to date showed marked increases in rainfall events above the standardized mean in the station. The Yenagoa station, on the other hand, experienced a surplus of rainfall from 1988 to 1997, and 2004 to 2006 as shown in Figure 5(e). Owerri, an outlier station of the Niger Delta Basin, was observed to have had 18 years of drought within the period of study. Its mean rainfall was also observed to be lower (that is, 1824.02mm) compared with those of Degema (2477.42mm), Port Harcourt (2258.02mm), Warri (2756.92mm), and Yenagoa (3300.04mm).

Although dryness or drought is conceptualized with reference to the calculated monthly and annual means of rainfall in the region, no severe droughts could be said to be experienced in the Niger Delta Basin. The region, located within the wet equatorial climate is dominated by warm, moist tropical and equatorial maritime air masses that yield heavy convectional rainfall all year round. Precipitation is plentiful in all months, and the annual total often exceeds 250cm (about 100 inches). The variability of rainfall in the region may be partly attributed to the seasonal pattern of rainfall in the region so that rainfall is greater during some part of the year. This period of heavier rainfall occurs when the inter-tropical convergence zone (ITCZ) migrates into the region (Strahler and Strahler, 2004).

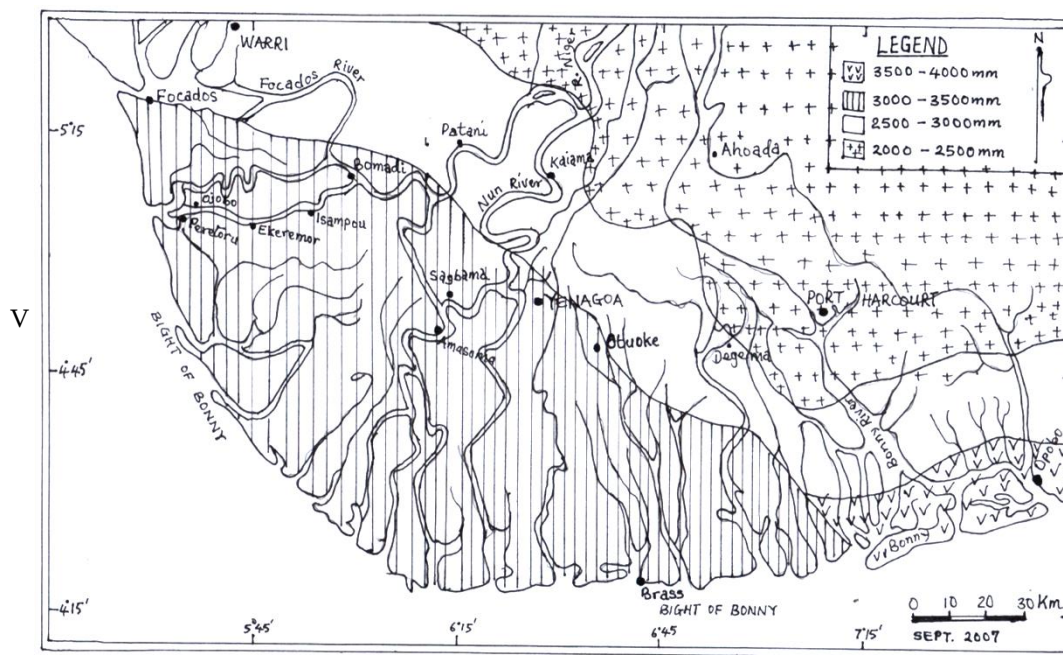


Fig.4: Rainfall Variability in the Niger Delta Basin

Source: NDRDMP, 2007

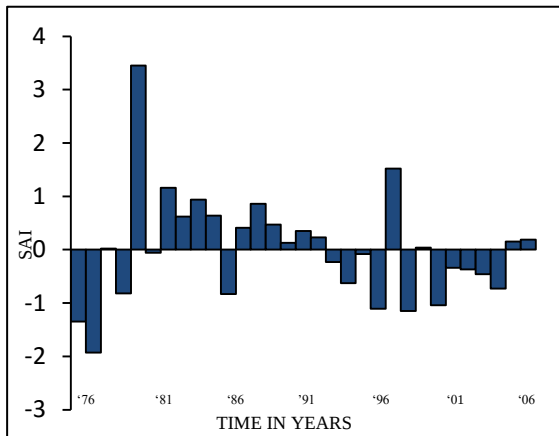


Fig 5(a): Inter-Annual Rainfall in the Niger Delta Basin: Annual Rainfall Variation in Degema (1976-2006)

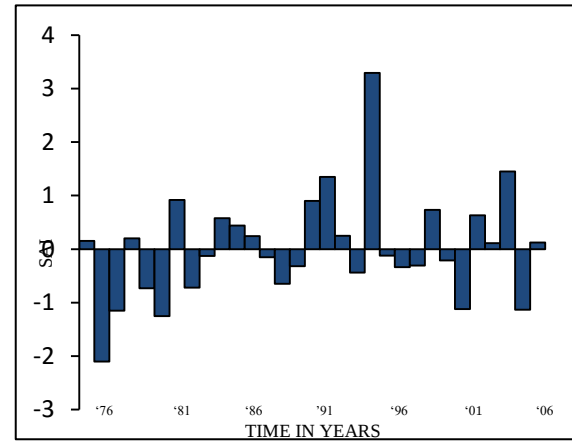


Fig. 5(d): Inter-Annual Rainfall in the Niger Delta Basin: Annual Rainfall Variation in Warri (1976-2006)

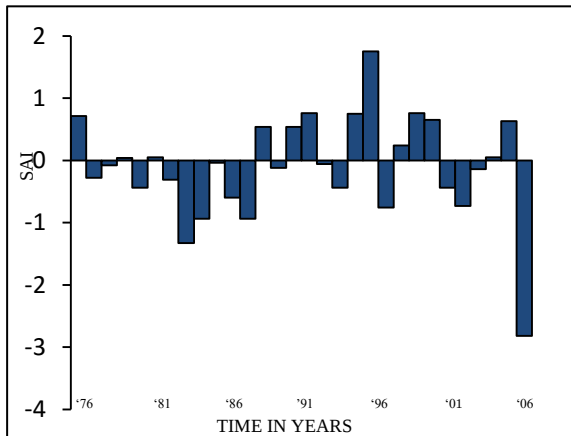


Fig. 5(b): Inter-Annual Rainfall in the Niger Delta Basin: Annual Rainfall Variation in Owerri (1976-2006)

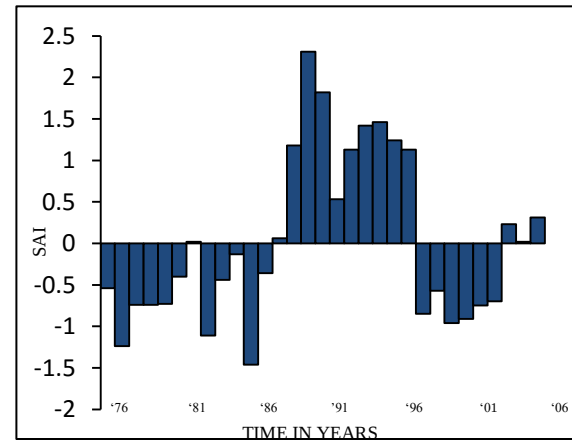


Fig. 5(e): Inter-Annual Rainfall in the Niger Delta Basin: Annual Rainfall Variation in Yenagoa (1976-2006)

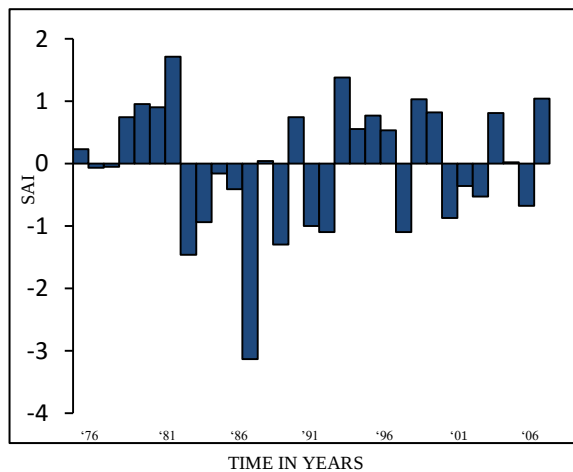


Fig. 5(c): Inter-Annual Rainfall in the Niger Delta Basin: Annual Rainfall Variation in Port-Harcourt (1976-2006)

KEY		
'76	-	1976
'81	-	1981
'86	-	1986
'91	-	1991
'96	-	1996
'01	-	2001
'06	-	2006
SAI	-	Standardized Anomaly Index

AVERAGE DEPTH OF PRECIPITATION OVER THE BASIN

Precipitation constitutes a major input into the hydrological system of any given area. An assessment of the mean depth of precipitation over the Niger Delta Basin is therefore very necessary since most hydrological problems, including flooding, requires a knowledge of the average depth of precipitation over a significant area such as a drainage basin and the way it is disposed off.

The mean depth of precipitation over the Niger Delta Basin is 2887.41mm approximately by our computation and this has some hydrometeorological implications in general, and in the production of surface run-offs and flooding specifically due to the lithology and topography of the region.

MAGNITUDE-FREQUENCY ANALYSIS OF RAINFALL IN THE NIGER DELTA BASIN

Generally, great magnitudes of floods correlate with low frequency while small magnitudes correlate with high frequency according to the Theory of Extreme Values (Garg, 2007). In order to assess the frequency of flood-producing rainstorms in the Niger Delta, the non-cyclical method of analysis provided by Gumbel (1941) was used. The results of the magnitude-frequency of rainfall in the Niger Delta, based on the Gumbel method as explained in the methodology is presented in Figures 6a-d.

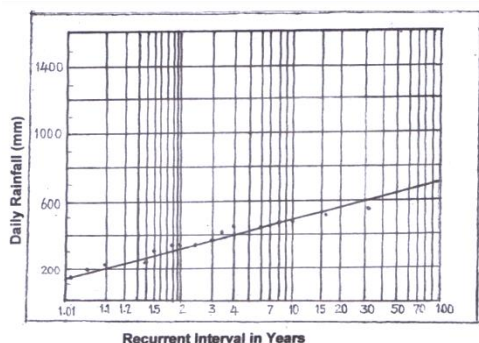


Figure 6 (a): Magnitude-Frequency of Rainfall in the Niger Delta Basin: Yenagoa Station (1976-2006)

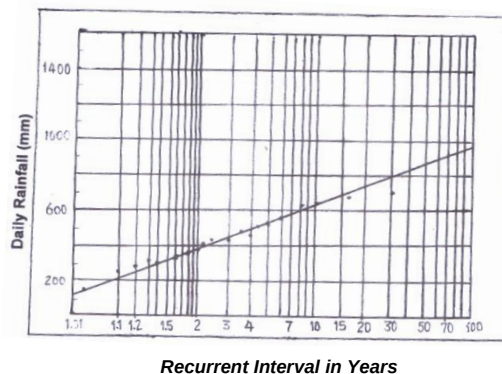


Figure 6 (b): Magnitude-Frequency of Rainfall in the Niger Delta Basin: Warri Station (1976-2006)

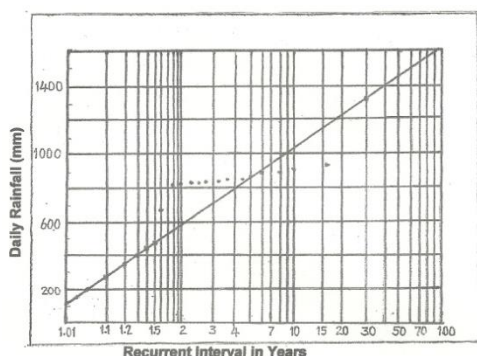


Figure 6 (c): Magnitude-Frequency of Rainfall in the Niger Delta Basin: Port Harcourt Station (1976-2006)

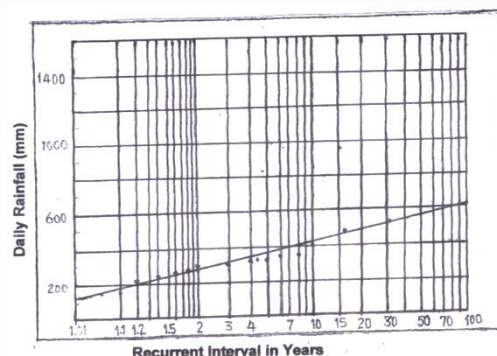


Figure 6 (d): Magnitude-Frequency of Rainfall in the Niger Delta Basin: Owerri Station (1976-2006)

With a series of 31 years of rainfall records for each station, the magnitudes of the 5-year, 10-year, 25-year and 30-year floods were satisfactorily defined. The defined mean annual floods, median annual floods – equaled or exceeded, the most probable annual floods and the corresponding recurrence – intervals are presented in Table 1. These floods come within the practicable limits of much engineering works, flood control, flood alleviation, and other design purposes in the Niger Delta Basin, and the adjoining outlier areas of Owerri.

Observable in the graphs (Fig.6), particularly against the recurrence interval of 100 years, rainfall peaks of 1600mm, 1000mm, 700mm and 600mm for Yenagoa, Warri, Port Harcourt and Owerri respectively could be read off as expectable annual maximum magnitudes once in a 100-year span. It must, however, be emphasized that there is nothing to prevent the occurrence of two 100-year rainfalls (floods) in two successive years.

Table 1: Magnitude-Frequency of Flood Producing Rainfalls in the Niger Delta Basin (1976 – 2006)

Point	Mean Annual Flood		Median Annual		Most Probable Annual	
Station			Flood		Flood	
	Return period (yrs)	Rainfall (mm)	Return period (yrs)	Rainfall (mm)	Return period (yrs)	Rainfall (mm)
Yenagoa	1.63	730	2.00	850	1.60	662
Warri	2.21	415	2.00	389	1.60	363
Port	2.07	353	2.00	359	1.60	345
Harcourt						
Owerri	1.85	295	2.00	308	1.60	264

THE PERCEPTION OF FLOOD HAZARDS IN THE NIGER DELTA BASIN

Responses to questions concerning the causes, magnitude (depth), frequency and the areal extent of flood coverage in communities and the region in general showed that many of the respondents interviewed had a fairly defined perception of flood hazards in the Niger Delta Basin.

Responses regarding opinions on the causes of flooding in communities showed wide variations among the respondents (Table 2). The respondents' perception of the causes of flooding included deforestation, heavy rains, indiscriminate dumping of refuse in drains and drainage paths, the will of God, sin and the desecration of the land and gods, and the rising sea level as well as the oil and gas mineral mining operations in the region. Other perceived causes of flooding mentioned in the interviews included over-bank flow of rivers and the topography of the region which is low and generally flat. Thus, 44.0% of the respondents indicated that torrential rainfalls were particularly responsible for flooding in the region. This was closely followed by flow of rivers when the river banks were breached (25.1%).

To some of the respondents (5.3%), flooding was seen as the act and will of God. This perspective however fails to recognize that many disasters are created by humans who misperceive, or choose to ignore their onset. Also, 3.2% perceived sin and the desecration of the land and gods, as well as other esoteric practices as veritable causes of flooding in the Niger Delta region; and that this could be remedied only by obedience to perceived principles of righteousness, environmental conservation and preservation, fervent prayers and good will to mankind.

Table 2: Perceived Causes of Flooding in the Niger Delta Basin

Perceived Causes of Flooding	Respondents	Percentage(%)
Heavy rainfall	264	44
Oil and gas mining operations	13	2.2
Sin and desecration of the land	19	3.2
Rising sea level	50	8.3
The will of God	32	5.3
Indiscriminate dumping of refuse	14	2.3
Over bank flow of rivers	151	25.1

Topography of the region	28	4.7
Structural failure	1	0.2
Deforestation	28	4.7
Total	600	100.0

Although the role of structural failures in causing flooding was not appreciated by the respondents, one householder however, recognized the potential effects of human activities upon flooding, specifying the effect of construction in the study area as a cause of flooding. Walls and compound demarcations were perceived as often impounding storm waters and lengthening the period of inundation; rendering roads and paths impassable, and the collapse of poorly structured buildings.

Though for almost all natural events, especially at the extreme end of the spectrum, some measurement of magnitude exists. The respondents, in the absence of relevant technologies, were unanimous in their estimates in citing the magnitude of flooding in the Niger Delta Basin. About 42.2% of the respondents who participated in the study asserted that residential areas were often inundated to 0.6 metres deep immediately after flash storms, necessitating the construction of stilted wooden walk ways. Another 18.5% of the respondents made their estimate at 1.2 metres deep. This is the case of river floodplain dwellers. And yet another 16% and 23.3% fixed their estimates at 1.8 metres and above 2.4 metres respectively. From the foregoing, the perceived magnitude of flooding could be seen to range between 0.3- 0.6 metres, and in extreme cases, at the flood fringes along the floodplain 1.8 - 2.4 metres after heavy rainstorms and high tides at the peak of the wet season.

On the areal extent of flooding in the Niger Delta Basin, 20.2% of the householders cited “the entire landscape” as being inundated. However, the absence of accurate gauging records and flood mappings made it really difficult for us to verify the areal extent of flooding precisely. Nevertheless, field evidences and the responses of householders from different communities in the region facilitated our delimitation of the areas liable to floods. From our base map, about 64,080SqKm or 80% of the region is perceived to be inundated during the rainy or wet season. This is presented in Figure 7.

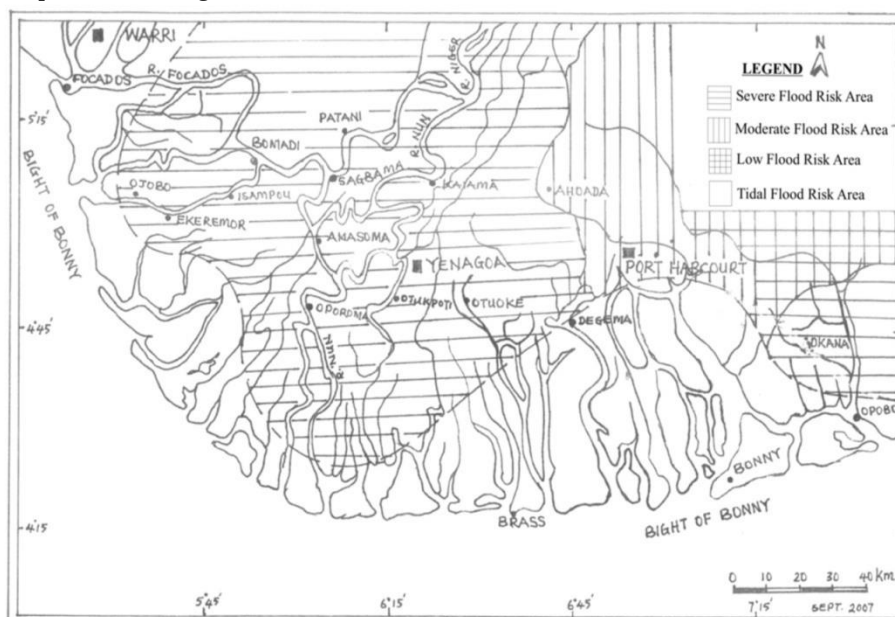


Fig.7: Spatial Variations in the Level of Flood Risk in the Niger Delta Basin.

Source: NDRDMP 2007

Generally, the respondents interviewed lacked any perception of the frequency of severe floods. However, 73.7% of the respondents stated that flooding occurred every year. The perceived annual flooding of the communities reflected the respondents' preparedness to make necessary adjustments to recurrent natural or man induced environmental hazards. Of the respondents who gave definite responses to the question on flood frequency, 10% selected the option "I don't know" and 7% opined that flood occurs "once in 5 years". The "I don't know" responses suggested some form of indecision on the part of the respondents as to what constitutes the frequency of a "severe" flood. The "once in 5years" responses on the other hand indicated the perceived severity and the cyclical nature of flood occurrence in the region. With the absence of detailed records of flood frequencies and magnitudes, it was difficult to assess the true situation with any degree of accuracy.

On the seasonality of flooding in the region, 37.6% of the respondents indicated that flooding is usually at its peak annually by September and this coincides with the peak of the rainy season when rainfall exceeds evaporation. About 54.7% of the respondents also indicated that the onset speed of flooding in the region is slow. This gives time allowance for such adjustments as flood warnings, evacuation planning and change of resource use in areas at risk.

Table 3: Perceived Frequency of Severe Floods in the Niger Delta Basin

Frequency of occurrence	Respondents	Percentage(%)
I don't know	60	10.0
Every year	442	73.7
Once in 5 years	42	7.0
Once in 10 years	35	5.8
Once in 20 years	21	3.5
Total	600	100.0

Interestingly, 34.2% opined that flooding is a heritage from God; and 11.8% perceives flooding as a great resource that creates other resources to be harnessed and utilized purposefully for multiple applications. Also, 29.3% of the householders perceived flooding to have the capacity to influence the ordering and use of space, management of time, and the planning and design of physical infrastructures; 24.7% perceives floods as capable of creating resistances. This perspective views regional floods as high waters that may inundate extensive regions for weeks causing deaths, extensive damages and severe test of human endurance. Annual or sporadic floods occur in large river valleys with low topography when prolonged heavy rains results from widespread cyclonic and convectional systems as it is evident in the Niger Delta Basin.

From Table 4, responses to known and adopted measures of flood alleviation in the Delta Basin fall into two main categories; Structural and Non-Structural. The observed structural responses in the region included building of artificial levees along rivers to contain flood waters inside larger channels, engineering projects seeking to increase the water-carrying ability of rivers via straightening, widening, deepening and removal of debris, and short-term actions such as sandbagging. The non-structural responses included stream gauging in some reaches for needed accurate flood forecasting and warning, zoning, land-use planning policies and education. On the measures generally known by the residents, 56.7% of the respondents indicated their awareness of drainage construction, 9.0% - structural stabilization of buildings and 19.2% - land reclamation via dredging and sand-filling, as structural responses. On the non-structural measures, 8.8% of the respondents indicated land use planning and zoning, 3.0%-selected re-afforestation, and 3.3%- resettlement.

In the assessment of flood-damage potentials in the Niger Delta Basin, 37.8% of the respondents were unequivocal in their statement of buildings and property damage while 2.7% mentioned loss of life (Table 4). Each

year, floods do more than 100 million naira worth of property damage, and often result in loss of human life. The 1999 floods in the Forcados and Nun River Systems alone drowned at least 20 people and left hundreds homeless, caused an estimated 10 million naira in damages (Roderick, 2004). Also, 35% of the respondents stated that croplands and livestock as well as social infrastructure (24.5%) stand the risk of flood – damage annually in the Niger Delta.

Table 3: Perceived Measures of Flood Alleviation in the Niger Delta Basin

Modes of flood alleviation	Respondents	Percentage(%)
Drainage construction	340	56.7
Structural stabilization	54	9.0
Land reclamation	115	19.2
Resettlement	20	3.3
Reafforestation	18	3.0
Land-use planning	53	8.8
Total	600	100.0

Table 4: Perceived Damage Potentials of Flooding in the Niger Delta Basin.

Damage potentials	Respondents	Percentage(%)
Buildings/properties	227	37.8
Croplands/Livestock	210	35.0
Social Infrastructure	147	24.5
Lives	16	2.7
Total	600	100.0

DISCUSSION

In order to determine the magnitude of floods in the study area, rainfall events were analyzed and the magnitudes obtained were used to make probabilistic estimates of rainfall for design purposes in the region. The 3-year moving average curves indicated a general trend of increasing rainfall events in the Niger Delta Basin except for the periods between 1986 to 1989 and 1995 to 2001 which indicated a decreased annual precipitation in the region. Even the outlier stations of the region, with lower incidence of rainfall indicated increasing trends of rainfall events from 2001 to date. While the coefficient of variation for annual rainfall ranges from about 10% in the south to 13% in the north, the inter-annual rainfall variability analysis, using the standardized anomaly-index, indicated that rainfall varies from year to year and from location to location in the Niger Delta Basin. While rainfall was quite variable in the 1990s, an increase in rainfall events is noticeable in the region till date. In this analysis, the Warri

station was observed to have had more of below mean rainfall events; the Yenagoa station, on the other hand, experienced a surplus of rainfall from 1988 to 1997 and 2004 to 2006. The outlier stations were observed to have had 18 years of drought, thus, the mean rainfall of the outlier stations (for example, Owerri – 1824.02mm) was observed to be lower compared with those of Degema (2477.42mm), Port Harcourt (2258.02mm), Warri (2756.92mm) and Yenagoa (3300.04mm).

Although by the inter-annual rainfall variability analysis, dryness or drought was conceptualized with reference to the calculated monthly and annual means of rainfall in the region, no severe droughts could be said to be experienced in the Niger Delta Basin.

Assessment of the mean depth of precipitation over the Niger Delta Basin was achieved by the equivalent uniform depth method and this was determined to be 2887.41mm approximately. On the magnitude-frequency analysis of flood-producing rainfall in the basin, the magnitudes of the 5-year, 10-years, 25-years and 30-years floods were satisfactorily defined (Table 4). These floods come within the practicable limits of most engineering works, flood control, flood alleviation, and other design purposes in the Basin, and the adjoining areas. At the recurrence-interval of 100-years, flood peaks of 1600mm, 1000mm, 700mm and 600mm for Yenagoa, Warri, Port Harcourt and Owerri were read off as expectable annual maximum magnitudes. On the average, at least a flood magnitude of 975mm is expected at the 100-year recurrence-interval in the year.

The determined flood magnitudes are influenced by several factors or controls in the Niger Delta Basin which contributes to regulating the ways in which the rivers and the entire region respond to precipitation and the recurrence of the observed flood magnitudes. These controls are: (a) Size of the drainage basin. The Niger Delta Basin is the world's third largest wetland (NDRDMP, 2007). With an area of about 80,100Sq.Km located within the Equatorial Forest, the total flood flows take considerable time to pass the outlet, thus influencing the base of the hydrograph of the flood flows which are widened out, thereby reducing the peak flows in the region (that is, the lag time is longer here). (b) Prolonged rainfall. The wet season here is relatively long, lasting between seven and eight months of the year, from March to October. The region has a mean annual rainfall of over 4000mm in the coastal areas, 3000mm in the mid-delta and 2400mm in the northern parts. Floods frequently occur as the ground becomes saturated and infiltration replaced by surface runoff (overland flow). (c) Basin slope. The region is an area of lowland traversed by many rivers, creeks and back-swamps that are very liable to flooding. (d) Tides and storm surges. The rising sea level and tides tend to prevent river flood waters from escaping into the sea. Flood waters therefore build up in the lower reaches of the basin. When high tides coincide with gale force winds blowing onshore, the results are often storm surges. These are common experiences in the Burutu, Forcados, Bonny and Brass areas of the region.

The human activities that increase the risk of flooding vis-à-vis the observed catchment characteristics in the basin include: (a) Urbanization: Rapid floodplain development for industrial, commercial, residential and recreational uses has reduced infiltration through tarmac and concrete works, and gutters and drains carry water more rapidly to the nearest natural depressions and rivers. Small urban streams are often canalized in the region so that water flows away more rapidly; or culverted, which allows a limited amount of water to pass through at one time. (b) Clear cutting of large areas of forestlands for agricultural and social uses. (c) Indiscriminate dumping of refuse and misuse of river channels and wetlands, (d) Gas and oil mineral mining operations, and (e) Misperception and use of water resources in the region increases the risk of flooding in the Niger Delta Basin.

CONCLUSIONS

In the Niger Delta Basin, annual and sporadic floods are influenced by rainfall. The rainfall characteristics of the region showed a general trend of increasing rainfall events from 1976 to date except for the periods between 1986 and 1995 to 2001 which indicated annual precipitation decreases with a great temporal and spatial rainfall variability from year to year and from location to location. The coefficient of rainfall variation in the basin ranges from 10% in the south to 13% in the north, and the basin has a mean depth of precipitation of about 2887.4mm. At the recurrence-interval of 100-years, flood peaks of 1600mm, 1000mm, 700mm, and 600mm for the Yenagoa, Warri, Port Harcourt, and the Owerri stations respectively were determined as expectable annual maximum magnitudes, and 975mm as the minimum. On the perception of floods in the Niger Delta Basin, the interviews demonstrated a very high level of awareness (95.3%) that the region was flood-prone particularly during the wet season. The resource users' perception of floods and flood hazards showed some association with ethnicity, the

socio-economic characteristics of the resource users, educational status, occupation, floodplain land-use designations and the resource use patterns in the region.

In the absence of relevant technologies, the respondents made crude estimates of the magnitudes and areal extents of flooding in the region (0.6m to 1.2m deep; and the entire landscape respectively), but lacked any perception of the frequency of severe floods in the region. The determined flood magnitudes were influenced by such catchment characteristics as the size of the drainage basin, the rainfall patterns, the basin slope, tides and storm surges; as well as such anthropogenic activities as urbanization, deforestation for agriculture and other social uses, indiscriminate dumping of refuse and the misuse of river channels and wetlands, oil and gas mining operations and the misperception and use of water resources in the region which have increased the risk of flooding in the Niger Delta Basin.

RECOMMENDATIONS

The excessive reliance on technology in the 1960s only opened a limited range of technologically oriented adjustments for controlling natural events and their consequences in the industrial nations and countries with a mixed society. The many small-scale individual adjustments used by farmers in hazard zones were, however, not often encouraged or supported by national action. As this weakness of hazard-event control programme become apparent, a growing recognition of the need for a more comprehensive flood damage reduction was canvassed and adopted in the United States and Britain in the 1970s.

For the implementation of technologically oriented adjustments for controlling flood events in the Niger Delta Basin, more detailed research aimed at an accurate forecasting of events is needed in many other aspects of flooding in the region. Parameters such as flood magnitudes, frequency, areal extent of coverage, size of drainage systems and the flood potentials of existing streams must be carefully studied. These parameters, if properly documented and analyzed, will enhance each individual attempt to minimize the economic loss from a hazardous event by the adoption of the most efficient combination of damage-reducing adjustments; weighing the risks of the hazard and the degree of proper or social damage that might occur against the costs of the various adjustments that are available.

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